Sources of Uncertainty in Rain and Latent Heating Retrievals

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1. INTRODUCTION

The proposed Global Precipitation Mission (GPM) provides an unprecedented opportunity for monitoring the Earth's climate system through mapping of global rainfall and diagnosing the exchange of energy throughout the tropics, subtropics, and polar areas. Based on the highly successful Tropical Rainfall Measuring Mission (TRMM), GPM will combine passive microwave observations of cloud systems with active, space-based weather radar to relate observed cloud properties to low-level precipitation and the vertical profiles of latent heat that help drive global atmospheric circulations.

Validating the retrievals of precipitation and latent heating from the satellite-based observations will be challenging, especially in light of the difficulty experienced during TRMM. However, retrieval techniques are maturing. And the experience gained under TRMM has left us poised to address the uncertainty in rain and latent heating retrievals in an effort to devise a better validation strategy. This paper describes results from recent studies aimed at determining the magnitude of uncertainty in some of the retrieval steps. By focusing on the physical aspects of the measurements and the procedures used in the retrievals, we should be able to avoid some of the validation miscues made during TRMM.

2. METHODOLOGY

To evaluate the uncertainty in retrievals of rain and latent heating we created a database of cloud properties and microwave brightness temperatures at TRMM frequencies using a non-hydrostatic cloud-resolving model and a radiative transfer model. Empirical Orthogonal Function (EOF) analyses of the vertical profiles from numerous numerical simulations were used to derive relationships between passive microwave brightness temperatures and cloud properties (surface rainfall, hydrometeor profiles, radar reflectivity profile, and vertical profile of latent heating). Observed brightness temperatures from the Advanced Microwave Precipitation Radiometer (AMPR) were used to drive retrievals of the cloud properties from the model database. Comparisons were made to evaluate the uncertainty that different properties or procedures would have on the retrieved rain total and mean latent heating profile.

3. RESULTS

Table 1 lists the parameters and procedures that were examined and their impact on the retrieval of total rain for the case examined. In should be noted that the tests were designed to evaluate the impact of modest, rather than drastic, changes. It should also be noted that the results are based on a relatively small set of simulations (12 realizations of the 22 Feb 93 TOGA-COARE squall line and 5 realizations of the 29 August 1999 KWAJEX squall line). This is about three times the number of simulations that make up the official retrieval database for TRMM. The analyses here are focused on tropical oceanic squall line systems. Other storm types (i.e. shallow convection, tropical cyclone, mid-latitude frontal systems, etc.) may not be well represented by these results.

4. RECOMMNEDATIONS

The results of the study indicate that retrievals of rain from passive microwave observations are sensitive to the microphysical parameterizations used in the cloud models as well as the fall speeds being assumed for the highest density ice particles. Validation activities should help address these sensitivities by providing a robust data set of simultaneous observations of hydrometeor profiles, densities, fall speeds, radiative properties and cloud dynamics in a variety of cloud systems. The sensitivity to model manifold (i.e. the retrieval data base) is surprising since both simulations are tropical oceanic squall lines and were conducted with the same cloud model. This emphasizes a need for the GPM validation program to CAREFULLY select its validation sites so as to be as representative as possible.

The other region of strong sensitivity is related to echo classification. Echo classification under TRMM has generally followed a binary (convective or stratiform) scheme. The partitioning of the model database used for the retrievals is done by a similar binary scheme. Hence, there are distinctly different EOF coefficients for the rain retrievals depending on whether an observation is tagged convective or stratiform. Since echo classification represents one of the greatest sources of uncertainty in rain retrievals, GPM should revisit how the retrieval process can be modified to account for what can and can not be determined with regard to the type of cloud being observed. From a validation point of view, if the retrievals make use of echo classification then that classification has to be validated relative to how it is used. It should be noted that the question of whether or not an area of cloudiness is convective or stratiform is only relevant in regard to how that information is used in the retrieval process based on the combined space-borne sensors.

For GPM, the retrieval algorithm's key assumptions and steps need to be validated. Instead of investing the majority of the resources in generating maps of rainfall that only check the results of the integrated procedure, the validation program should focus on improving the elements of the retrieval of precipitation and latent heating from the spaceborne observations.

Improving and expanding the cloud-radiative database used in the retrievals is also a critical issue. These should be done thoughtfully in a manner that can be checked against sets of observations to ensure appropriate multidimensional brightness temperature relations and realistic profiles of hydrometeors. The validation program should be based on establishing a small number of observational super-sites that can sample a wide range of cloud systems to aid in expanding the model manifold. Numerous targeted field campaigns at the super-sites and in other, less represented regimes, should be conducted to validate the models used in the retrieval database as well as the physical basis of the retrievals themselves.

Table 1: Parameters and Procedures Tested

Parameter/Procedure	**Description**	**Impact (Total Rain)**
Microphysical Parameterization	Hybrid Rutledge and Hobbs (1984) vs. graupel version of Lin et al. (1983)	±7% with stratiform uncertainty twice convective uncertainty
Drop Size Distribution	Assumed Marshall-Palmer (1948); intercept varied from to one to three times and eight times MP value; rain always twice graupel	± 3% for factor of 3 change; ±15% for factor of eight change
Graupel Density	Values ranged from 600-900 kg m^{-3}	< ± 3%
Hydrometeor Fall-speed Formula	RH84 vs. LFO formula	± 10% with largest impact for stratiform
Echo Classification Scheme	Biggerstaff and Listemaa (2000) vs. Steiner et al. (1995)	±10% with BL00 giving more rain
Radiative Transfer Model	Monte Carlo vs. Eddington	< ± 3%
Inversion Method	EOF vs. Bayesian	± 5 % convective
Model Manifold	TOGA-COARE vs. KWAJEX squall line simulations; retrieval driven with KWAJEX observations	± 8 %